CONTRIBUTION TO THE GENESIS OF FRESHWATER LIMESTONES IN THE VICINITY OF BUDAPEST

GY. VITÁLIS — J. HEGYI-PAKÓ

Geological setting

The presence of a host of hot spring traces in the neighbourhood of Budapest, i.e. in that part of the Hungarian Central Range extending from the valley of the Általér up to the valley of the Galga, suggests that the hot spring activities in the pre-Holocene geological periods must have been much more intense and extended than are at present. Such a hot spring activity is most typical, as suggested by the surface extension and thickness of Upper Pannonian, Levantine, Pleistocene and Holocene freshwater limestones, of the Pleistocene epoch.

The surface extension of major freshwater limestone patches is shown in *Fig. 1.* For a better orientation, the volcanic areas of the Danubian andesite range (Visegrád Mts., Börzsöny Mts.) and of the SW Cserhát range are also shown in *Fig. 1.* as the setting in of hot spring activities can be connected partly with the hydrothermal aftermath of the Mid-Miocene andesite volcanism. This has been responsible for the hydrothermal metasomatism and the sinter mounds discovered in the carbonate complexes adjacent to the volcanic areas. Changes due to hot spring activities and hydrothermal metasomatism in the Triassic carbonate rocks (limestone, dolomite) in the vicinity of Budapest, adjacent to the Danubian andesite range were deslt with in earlier studies by the authors (*Gy. Vitális—J. Hegyi-Pakó* 1974, 1976), whereas the problems of siliceous hot spring activities were discussed by others (*H. Böckh* 1899. *F. Papp* 1957, *P. Pelikán* 1973, *A. Vendl* 1934).

Hot spring action in Miocene time started even independently of the volcanic aftermath, as soon as the impervious layers overlying the karstic-water-bearing Triassic limestones and dolomites were removed by the infra-Oligocene denudation processes and thus lost to erosion and the hot and subthermal waters reached up to the surface along faults due to tectonic movements. The spring exit points and, consequently, the places of freshwater limestone precipitation, were shifted as a result of uplifts and subsidences due to subsequent orogenic movements.

The spatial setting of both the Tertiary volcanic complexes indicative of the — earlier — juvenile thermal springs and of the mainly Triassic limestone and dolomite complex storing vadose (karstic) thermal waters currently welling up, or expected to well up, to the surface is illustrated by the geological block-diagram of *Fig. 2.* Where the karstic-waterbearing limestone and dolomite complexes are overlain by heat-insulating clays and clay-marls of mainly Oligocene age and considerable thickness, thermal waters of comparatively high temperature are likely to well up to the

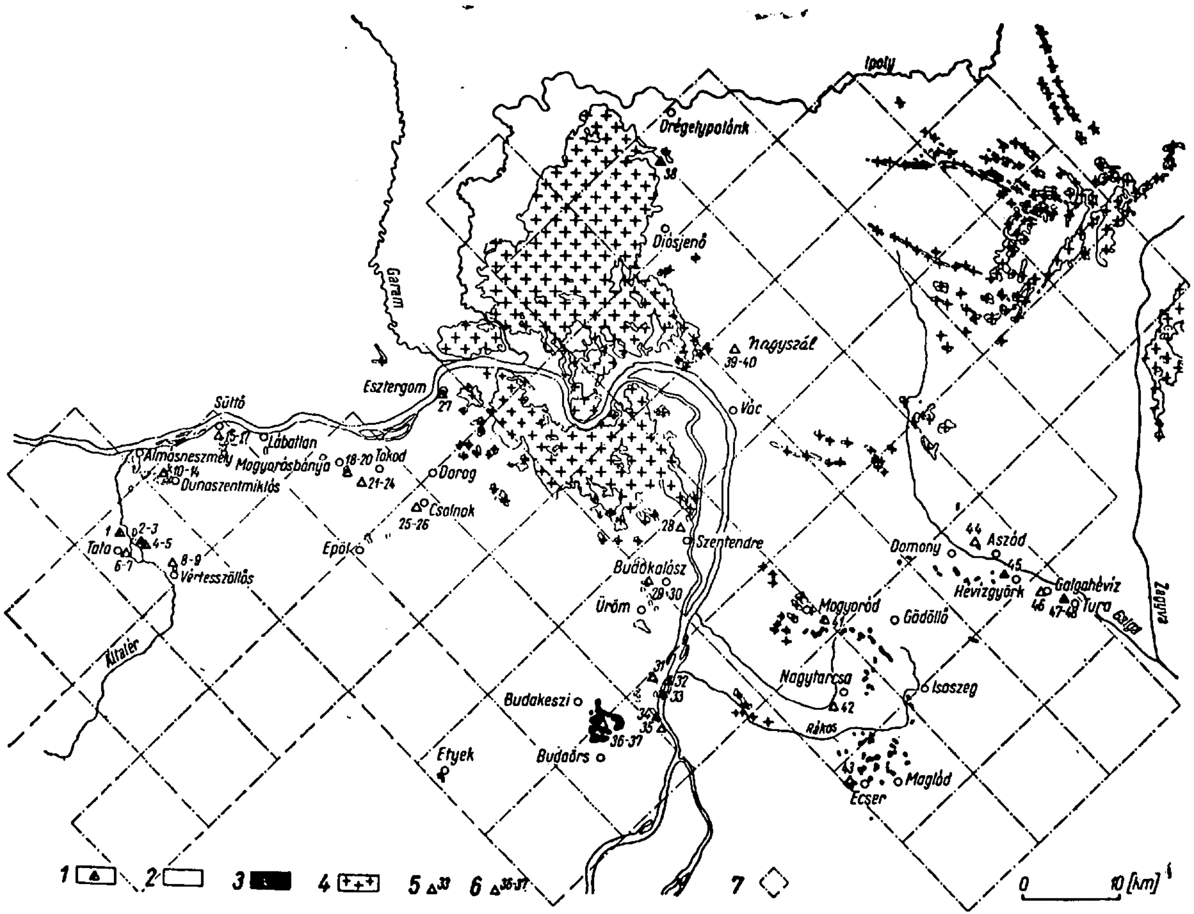

Fig. 1. Geological chart outlining the freshwater limestone deposits in the surroundings of Budapest (Based on cartographic information of the Hungarian Geological Institute)
1. Freshwater limestone (Holocene); 2. Freshwater limestone (Pleistocene); 3. Freshwater limestone (Levantine to Upper Pannonian) 4. Andesite, andesite tuff, rhyodacite, rhyolite tuff (Tertiary); 5. Sampling point (one sample); 6. Sampling points (several samples); 7. Trace line of the block-diagram.

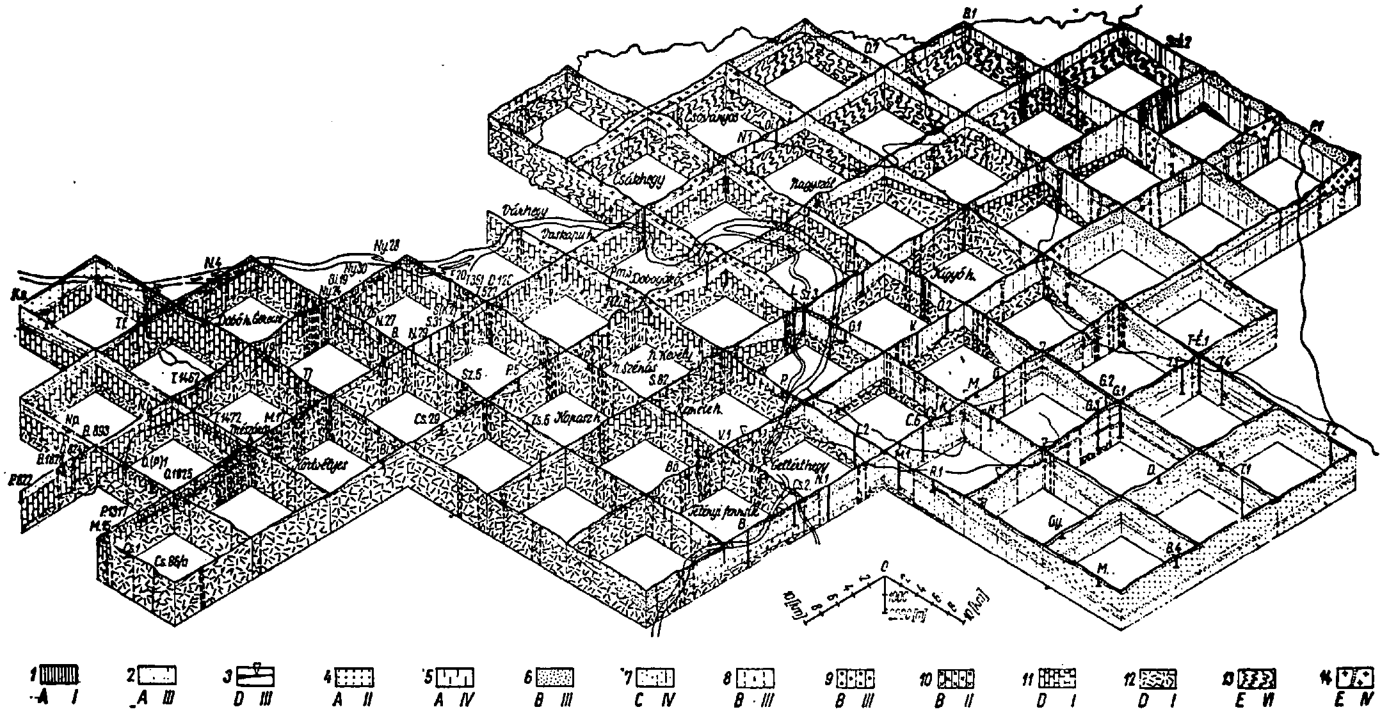

Fig. 2. Hydrogeological block-diagram (base level of reference: — 2000 m Baltic Sea) accross the central part of the Hungarian Central Range (Budapest region) 1. Sand, pebble, 2. Sand, pebble, loess, clay (Holocene—Pleistocene); 3. Freshwater limestone (Pleistocene to Upper Pannonian); 4. Sand sandstone, clay (Upper Pannonian); 5. Clay, clay-marl, sandstone (Lower Pannonian); 6. Clay, clay-marl, marl, limestone, pebble (Miocene); 7. Clay, clay-marl, sand, sandstone (Oligocene); 8. Clay, marl, limestone (Cretaceous); 10. Limestone, marl (Jurassic); 11. Limestone [marl, dolomite] (Triassic); 12. Dolomite [marl] (Triassic); 13. Shale, phyllite, micaschist, gneiss (Palaeozoic); 14. Andesite, andesite tuff, rhyodacite, rhyolite tuff (Tertiary). A. Ground- and formation waters, B. Formation and karstic waters, C. Formation waters, D. Karstic waters, E. Fissure waters are likely to be accumulated or tapped with the following characteristics: 1. Very good aquifers (with yields of 1000 to 10 000 m³ p. day ore more), II. Good aquifers (500 to 1000 m³ p. day), III. Good to fair aquifers (100 to 1000 m³ p. day), IV. Fair aquifers (100 to 500 m³ p. day), V. Fair to poor quifers (10 to 100 m³ p. day), VI. Poor aquifers (below 10 m³ p. day) alternating with impervious rocks. (According to the classification adopted for the Hydrogeological Atlas of Hungary, the above figures indicate the average water yield recoverable from each formation by one well.)

surface or to be tapped by water-development facilities. The precipitation of freshwater limestone, however, depends not on the water temperature, but primarily on the amount of dissolved salts (calcium-hydrogen carbonate) in the water.

If the position of the freshwater limestone deposits on the outline geological map-scheme *(Fig. 1.)* is compared with the distribution of the basement rocks schown in the hydrogeological block-diagram *(Fig. 2).* the freshwater limestones will be observed to rest on a karsted basement (Triassic limestones and dolomites) throughout the study area.

Since the freshwater limestones are insignificant in volume compared to the bulk of formations shown in the block-diagram, special attention is called to them by the triangular symbol pointed upside-down in *Fig. 2.*

Where the Mesozoic basement lies at, or close to, the land surface, thick freshwater limestone complexes occur (e.g. the Gerecse, Pilis and Buda ranges), while the major, deep-subsided Mesozoic blocks are known to carry a rather thin freshwater limestone overburden (e.g. the SW Cserhát).

Above Tertiary-andesite-covered Mesozoic formations Upper Tortonian freshwater limestone and silica deposits occur in the Puncz graben to the south fo Szokolya and to the NE of Verőcemaros (*H. Böckh* 1899) and may be considered to represent precipitates from postvolcanic thermal waters. Cold-water spring-deposited freshwater sediments above the andesite complex are known to occur near Szentendre (*Gy. Wein* 1939), Leányfalu (*L. Majzon* 1933), Diósjenő (*J. Noszky* 1941a) and Drégelypalánk (*J. Noszky* 1941b). These are of nonkarstic origin but derive, like the freshwater limestones being deposited on the Danube bank at Vác, from springwaters of comparatively higher lime content. The thermal waters so far tapped by wells in the Mesozoic basement in Tertiary andesite areas or adjacent to them (e.g. Lepence valley at Visegrád, Leányfalu beach, Pap-sziget at Szentendre, Vác beach), however, are not liable to freshwater limestone precipitation.

The geology of the freshwater limestone deposits in the surroundings of Budapest (*J. Cholnoky* 1940, *H. Horusitzky* 1938, *Á. Jámbor et al.* 1966, *T. Kormos—Z. Schréter* 1917. *P. Kriván* 1964, *E. Krolopp et al.* 1976, *I. Lőrenthey* 1906. *J. Noszky* 1925, *M. Pálfy* 1901. *M. Pécsi* 1959, 1973, *M. Pécsi—S. Marosi—J. Szilárd* (Editors) 1958, *Gy. Scheuer—F. Schweitzer* 1970a, 1970b, 1972. 1973, 1974, 1978, *Z. Schréter* 1953, *J. Szabó* 1879, *F. Szentes* 1943, 1950. 1968, *F. Szentiványi* 1932, *Gy. Wein* 1977) and the hot spring action responsible for them (*L. Alföldi* 1979, *H. Horusitzky* 1926. *L. Jakucs,* 1950, *F. Schafarzik* 1928, *E. Scherf* 1928, *Gy. Scheuer—F. Schweitzer* 1980, 1981a, 1981b, *Z. Schréter* 1912a, 1912b, *A. Vendl* 1944) have been dealt with by renowned scientists for more than a 100 yeras now. As a result of these works the evidence concerning the freshwater limestones is very rich. Regardless of some valuable detail informations (*A. Balogh* 1982, *M. Pécsi* 1973, *Z. Schréter* 1953), laboratory analyses and evaluations based on such are missing. The present paper has been intended to contribute some information of this kind and to convey some ideas on the matter.

Analyses and testing of materials

The locations of the samples of rocks of different age sampled during the study of freshwater limestones in the surroundings of Budapest are shown in *Fig. 1.* The samples have been selected so as to be representative of the individual subareas, the typical lithofacies and the geological time-spans of freshwater limestone formation alike.

The chemical, thermic and X-ray analyses of the samples were carried out at the Department of Silicate Chemistry of the Central Research and Design Institute for the Silicate Industry. The spectral analyses were performed by *M. Ihász—Horváth* of the Central Institute of Mining Development. The analyses were published in detail on pages 74—79 of Fascicle 2, Vol. 1982 of *Hidrológiai Közlöny* (Official Journal of the Hungarian Hydrological Society). The reader is referred to consult Table 1 in the afore-mentioned publication *(Gy. Vitális—I. Hegyi 1982).*

So diversified analytical data other than these concerning the Hungarian freshwater limestones are not known in the Hungarian geological and hydrogeological literature. For his reason, no far-going conclusion can be drawn from the results of the samples, rather few in number, collected and examined by us. Thus the results presented here are recommended as basic and comparative data to be used for continued research and the statements made here are hoped to excite ideas.

The chemical and mineralogical analyses of the samples agree as a rule with those of the socalled typical freshwater limestone. The lithological term for the samples of higher MgO content has been used, on the basis of the CaO/MgO ratio, according to Bárdossy's nomenclature. In case of several samples, however, the presence, of varying amounts (a max. of 42.54%) of SiO_2 is remarkable. The samples in which SiO_2 is present as free quartz are referred to as "siliceous" in the lithological designation (see hereinafter).

SiO_2 content (%)	Lithological term
2.00 to 2.50	slightly siliceous
2.51 to 5.00	fairly siliceous
5.01 to 10.00	siliceous
above 10.00	heavily siliceous

The presence of clay minerals identified by thermic analysis has been referred to as "argillaceous" in the lithological denomination of the samples.

According to the thermic and X-ray analyses, the predominant mineralogical component of the samples is *calcite*, frequent are *quartz* and *dolomite,* while *organic matter* and the *illite* and *kaolinite* clay minerals and, finally, *feldspar,* are subordinate. The freshwater limestone precipitated from thermal wells contains some *aragonite* and, in one case, some *rhodochrosite* as well.

During spectral analysis all trace elements were determined in every sample. On account of the extensiveness of the data files in question and of the identity of the elements in all samples (e.g. B, Co are less than 10 ppm; Th, Sr, Nd are present in a quantity of 100 ppm or so) the trace element figures are omitted here.

Table 1.

EXTREME AND AVERAGE VALUES OF PECULIAR TRACE ELEMENTS ACCORDING TO GEOLOGICAL AGES (in ppm)

	Cu	Sn	Pb	As	Ni	Cr	Ba
Holocene							
(11 samples)							
min.	5	10	10	23	10	3	44
max.	180	84	38	72	33	50	300
average	78	42	18	48	18	14	160
Pleistocene							
(24 samples)							
min.	30	5	10	50	10	3	5
max.	160	83	92	120	92	65	300
average	73	22	20	63	22	14	96
Levantine to							
Upper Pannonian							
(13 samples)							
min.	6	8	10	10	10	3	28
max.	160	140	28	92	55	55	300
average	48	28	14	50	20	18	148

Remark: The extreme and average values in the tabulation are data of different rock samples.

Table 2.

EXTREME AND AVERAGE VALUES OF PECULIAR TRACE ELEMENTS ACCORDING TO REGIONAL UNITS (in ppm)

	Cu	Sn	Pb	As	Ni	Cr	Ba
Gerecse Mts.							
(26 samples)							
min.	23	5	10	10	10	5	12
max.	130	83	92	88	92	55	300
average	58	22	20	60	23	15	100
Pilis Mts. and inselbergs in the vicinity of Vác							
(6 samples)							
min.	50	15	13	50	10	3	5
max.	180	84	34	64	46	65	300
average	98	38	18	52	23	22	106
Buda Hills							
(7 samples)							
min.	40	12	12	50	10	3	15
max.	180	46	38	120	30	11	300
average	115	27	18	73	15	5	123
SW Cserhát							
(8 samples)							
min.	5	17	10	23	10	4	110
max.	160	140	28	92	50	40	300
average	36	60	13	42	18	19	232

Remark: The extreme and average values in the tabulation are data of different rock samples.

Of the trace elements examined only Cu, Sn, Pb, As (calcophile elements) and Ni, Cr (siderophile) and Ba (alkali earth) exhibit some diversity. Their extreme and average values according to geological age and regions (subareas) are given in *Tables 1* and *2*, respectively. Acoordingly, Ba and Cu show the greatest amplitude of variation, Pb being least variable.

Comparing the quantities of the seven selected trace elements according to geological age and subareas, one can find that in the Holocene and Pleistocene freshwater limestones these are present in an almost identical total amount (378, 370 ppm) on the average, while the Levantine and Upper Pannonian limestones are characterized by a lower figure (326 ppm). In terms of subareal distribution, the seven trace elements show an almost equal total amount (100, 106, 123 ppm) in the freshwater limestones of the Gerecse, Pilis and the inselbergs near Vác and the Buda Hills, while the value obtained for the SW Cserhát area is almost the double of that figure (232 ppm).

Let us note here that the trace element studies carried out so far are in themselves unsuitable for distinguishing between freshwater limestones according to geological age and subareas.

A comparative evaluation of the geological features and the analytical results

In the light of geological observations and analytical results and a critical evaluation of the relevant literature the study of the intricate genetics of the freshwater limestones in the neighbourhood of Budapest has led to the following conclusions.

a) The *springs* that deposited the freshwater limestones — excepting the cold-water springs responsible for the Holocene ones — are considered to have been subordinately juvenile, but predominantly vadose (karstic water) in origin. It should be borne in mind especially that the Levantine to Upper Pannonian freshwater limestones of the SW Cserhát — discontinuous deposits forming no extended bed, lying close to major faults and showing the richest trace element content — are not considered to be inland sea deposits, but rather to be heavily truncated remnants of the sediments of one-time hot springs (that may have poured their discharge into the lagoons of an inland sea at the most). This hypothesis is confirmed by the almost identical trace elements observed in the freshwater limestone precipitated from the 2800-m-deep thermal well at Tura and the freshwater limestones in its immediate neighbourhood.

b) The *chemical composition* of the freshwater limestones is indicative of both the one-time hot spring water and the deep-situated rocks. In this respect, it is interesting to note that freshwater limestones of higher SiO_2 content (siliceous to heavily siliceous, suggestive of partly juvenile origin) occur primarily in the western (Vértesszöllős, Tata Dunaszentmiklós) and eastern (Hévízgyörk, Ecser) parts of the area. The higher SiO_2 content may partly derive from fine-grained sands transported as a suspended load by the one-time springwaters.

Dolomitic freshwater limestones of comparatively high MgO content precipitated from dolomite-stored karstic waters (1.97 to 9.76% MgO) can be found only in the Gerecse and Pilis areas.

The occurrence of higher SiO_2 (2.40 to 13.49%) and higher MgO (1.97 to 3.14%) contents combined, e.g. in the freshwater limestones precipitated from the Tükör spring at Tata, on the Kőhegy at Mogyórósbánya, the Kőpite at Dunaszentmiklós and in the Szelim valley at Szentendre, is an interesting phenomenon. This fact also indicates that geographically closely spaced freshwater limestone deposits, may have precipitated from springs deriving from lithologically different aquifers belonging to various tectonic units.

c) The *trace elements* identified in freshwater limestones suggest that the thermal waters received admixtures of ore-bearing solutions (*F. Horusitzky—Gy. Wein* 1962, *Gy. Wein* 1977) that had been produced by dissolution of metasomatic, skarnous and polymetallic, mainly sulphide, ore deposits supposed to have been brought about by Tertiary volcanism that affected chiefly Triassic carbonate sediments (*Gy. Vitális—J. Hegyi-Pakó* 1973).

d) In the light of a comparative evaluation of geological and laboratory analytical results freshwater limestones of different *genetic types* deriving from different water reservoirs can be distinguished. The main types distinguished in terms of chemical composition and their geographic distribution are summarized as follows.

The extreme and average values of the predominant components of the *typical freshwater limestone* are the following:

%	minimum	maximum	average
CaO	51.13	55.91	53.60
MgO	0.03	2.06	0.88
SiO_2	0.01	1.81	0.87

The extreme and average values do not represent in any case data of one and the same rock samples.

The greatest geographic extension of the typical freshwater limestone can be found in the Gerecse Mts (Tata W, Almásneszmély, Süttő, Mogyorósbánya and Tokod), the Pilis Mts. (Budakalász and Üröm), throughout the Buda Hills and in the SW Cserhát range (near Mogyoród).

The *argillaceous freshwater limestone* is characterized, in terms of clay minerals, by its SiO_2 and Al_2O_3 contents. SiO_2 varies between. 7.90 and 17.44%, Al_2O_3 between 3.76 and 8.85%. This rock is known to occur in fissures within the Ttiassic limestone sequence of the Nagyszál at Vác.

The *slightly siliceous, fairly siliceous, siliceous* and *heavily siliceous freshwater limestone* types are distinguished according to their SiO_2 content as described under the paragraph devoted to the laboratory analyses. *Slightly siliceous* freshwater limestone (SiO_2=2.00–2.50%) occurs at Tata and Drégelypalánk; *fairly siliceous* limestone (SiO_2=2.51–5.00%) at Tokod, Budapest Margaret Island, Galgahévíz; *siliceous* freshwater limestone (SiO_2=5.01–10.00%) is found at Vértesszöllős, Esztergom and Nagytarcsa; *heavily siliceous* deposits are known (SiO_2=above 10%) at Vértesszöllős, Dunaszentmiklós, Ecser, Aszód and Hévízgyörk.

The *dolomitic freshwater limestone* shows an MgO content varying between 1.97 and 9.76%. Most of the deposits of this kind also contain some SiO_2, 2.40 to 13.49%, thus this type can also be called *dolomitic and siliceous freshwater limestone.* The type is known to occur at Tata, Dunaszentmiklós, Mogyorósbánya, Csolnok and Szentendre.

* * *

The presence of freshwater limestones referred to as "siliceous" suggests that the activities of hot springs yielding siliceous waters did not cease by the end of the Pliocene, unlike believed by earlier authors (*F. Papp* 1957. *F. Schafarzik* 1928, *E. Scherf* 1928, *Z. Schréter* 1912a, 1912b, *A. Vendl* 1934, 1944), for their traces can be found in the Pleistocene and Holocene freshwater limestones as well.

REFERENCES

Alföldi L. (1979): Budapesti hévízek (Thermal waters of Budapest) — *VITUKI Közlemények*, 20. 1—102.

Balog, A. (1982): Néhány magyarországi hévíz szilárd kiválási termékének ásványtani és geokémiai vizsgálata (Mineralogical and geochemical study of solid precipitates from some Hungarian thermal waters) — *Hidrológiai Közlöny*, 62. 7. 312—318.

Böckh H. (1899—1902): Die geologischen Verhältnisse der Umgebung von Nagy-Maros. *Mitteilungen aus dem Jahrbuche der kgl. ungarischen Geologischen Anstalt*, XIII. 1. 1—63.

Cholnoky J. (1940): A mésztufa vagy travertino képződéséről. Über die Bildung von Kalksinter. *Matematikai és Természettudományi Értesítő*, LIX. 1004—1022.

Horusitzky F.—Wein Gy. (1962): Érckutatási lehetőségek a Budai-hegységben. The possibilites of ore prospecting in the Buda-mountains. *Bányászati Lapok*, 95. 11. 749—753.

Horusitzky H. (1926—1927): Hydrogeologie und nationalökonomische Zukunft der Thermen von Tata und Tóváros. *Mitteilungen aus dem Jahrbuche der kgl. ungarischen Geologischen Anstalt*, XXV. 3. 35—100.

Horusitzky H. (1938): Budapest Duna jobb parti részének (Budának) hidrogeológiája. Hydrogeologie der am rechten Donau-Ufer gelegenen Stadthälfte Budapests. *Hidrológiai Közlöny*, XVIII. 1—404.

Jakucs L. (1950): Újabb hozzászólás a Budai-hegység hidrothermáinak eredetéhez (A new contribution to the origin of the hydrotherms in the Buda Mountains) — *Hidrológiai Közlöny*, XXX. 233—235.

Jámbor Á. et al. (1966): Magyarázó Magyarország 200 000-es földtani térképsorozatához. L—34—II. Budapest (Explanation to the 200 000 geological map series of Hungary. L—34—II. Budapest) — Published by MÁFI, *Budapest*, 1—358.

Kormos T.—Schréter Z. (1917): Vorläufiger Bericht über die Untersuchung der an den Rändern des Budaer Gebirges und des Gerecse—Gebirges vorkommenden Süsswasserkalke. *Jahresbericht der Königlich Ungarischen Geologischen Reichsanstalt für 1915*, I. 583—585.

Kriván P. (1964): Erózióbázis feletti édesvízi mészkőalakulatok földtani vizsgálatának elvi alapjairól (On the principles of the geological investigation of freshwater limestone deposits above the base level — *Őslénytani Viták*, 2. 13—18.

Krolopp E. et al. (1976): A budai Várhegy negyedkori képződményei. Quaternary formations of Castle Hill in Buda. *Földtani Közlöny*, 106. 3. 193—228.

Lőrenthey I. (1906): Budapest pannoniai- és levantei-korú rétegei és ezek faunája (The Pannonian and Levantine sediments of Hungary and their fauna) — *Mathematikai és Természettudományi Értesítő*, XXIV. 2. 298—342.

Majzon L. (1933): Leányfalu és környéke harmadkori üledékeinek geológiai és paleontológiai leírása. Geologische und paleontologische Beschreibung der tertiären Schichten von Leányfalu und seiner Umgebung. A Ph. D. thesis. *Budapest*, 1—66.

Noszky J. (1925): Über die levantischen Quellenkalke auf der Pester Seite. *Földtani Közlöny*, LV. 386—387.

Noszky J. (1941a): A Duna bal parti hegyrögök környezetének geológiai viszonyai (Geological conditions of the mountain blocks of the Danube's left riverside) — *A MKFI Évi Jelentései az 1936—1938. évekről*, I. 473—501.

Noszky J. (1941b): A Börzsöny-hegység ÉK-i lábának földtani viszonyai. Die geologischen Verhältnisse des zwischen den Börzsöny- und Cserhát-Gebirgen liegenden Gebietes. *A MKFI Évi Jelentései az 1936—1938. évekről*, I 503—519. and 521—530.

Papp F.: (1957): Az ásvány- és gyógyvizek hidrogeológiája és fürdőtani leírása (Hydrogeology and balneological description of mineral and medicinal water resources) — In: Magyarország ásvány- és gyógyvizei (Mineral and medicinal waters of Hungary) — Editor: *Schulhof Ö.* Akadémiai Kiadó, *Budapest*, 15—334.

Pálfy, M. (1901): Geologische Notizen über einige Steinbrüche längs der Donau. *Földtani Közlöny,* XXXI. 5—6. 177—183.
Pelikán P. (1973): A budai-hegységi „gejzirit" vizsgálata (Study on the „geyserites" in the Buda Hills). Manuscript, Data Bank MÁFI, T: 5532.
Pécsi M. (1959): A magyarországi Duna-völgy kialakulása és felszínalaktana (Evolution and morphogenesis of the Danube Valley in Hungary) — Földrajzi Monográfiák (Monographs in Geography) III. Akadémiai Kiadó, *Budapest,* 1—346.
Pécsi M. (1973): Geomorphological position and absolute age of the lower paleolithic site at Vértesszőllős, Hungary. A vértesszőllősi ópaleolit ősember telephelyének geomorfologiai helyzete és abszolút kora. *Földrajzi Közlemények,* XXI. (XCVII.) 2. 109—119.
Pécsi M.—Marosi S.—Szilárd J. edit. (1958): Budapest természeti képe (The physical image of Budapest) — Budapest Földrajza (Geography of Budapest) 1. Akadémiai Kiadó, *Budapest,* 1—744.
Schafarzik F. (1928): Visszapillantás a budai hévforrások fejlődéstörténetére. Rückblicke auf die Entwickelungsgeschichte der Budapester Thermen. *Hidrológiai Közlöny,* I. 1921. 9—14. and 57—61.
Scherf E. (1928): Hydrothermale Gesteinsmetamoprhose im Buda—Piliser Gebirge. *Hidrológiai Közlöny,* II. 1922. 107—206.
Scheuer Gy.—Schweitzer F. (1970a) A karsztvíz eredetű édesvizi mészkövek csoportosítása (Grouping of fesh-water limestones of karst water origin) — *Földrajzi Értesítő,* XIX. 3. 356—360.
Scheuer Gy.—Schweitzer F. (1970b): Szempontok az édesvizi mészkőösszletek képződéséhez. Aspekte zur Bildung der Süsswasserkalksteinkomplexe. *Földrajzi Értesítő,* XIX. 4. 381—392.
Scheuer Gy.—Schweitzer F. (1972): Az édesvizi mészkövet lerakó karsztforrások paleogeográfiai viszonyai és osztályozásuk (Paleographic conditions and classification of karstic springs depositing travertine) — *Földrajzi Értesítő,* XXI. 2—3. 285—291.
Scheuer Gy.—Schweitzer F. (1973): The development of the Hungarian travertine sequences in the Quaternary. A magyarországi travertino összletek képződésének fázisai a negyedkorban. *Földrajzi Közlemények,* XXI. (XCVII.) 2. 133—144.
Scheuer Gy.—Schweitzer F. (1974): Új szempontok a Budai-hegység környéki édesvizi mészkőösszletek képződéséhez. New aspects in the formation of the fresh-water limestone series of the environs of Buda Mountains. *Földrajzi Közlemények,* XXII. (XCVIII.). 113—134.
Scheuer Gy.—Schweitzer F. (1978): Az édesvizi mészköveket lerakó források sajátosságai (Characteristics of springs dflpositing freshwater limestone) — *Földrajzi Értesítő,* XXVII 3—4 475—486.
Scheuer Gy.—Schweitzer F. (1980): A budai hévízforrások fejlődéstörténete a felsőpannontól napjainkig. Entwicklungspgeschichte der Budaer Thermalquellen vom oberen Pannon bis in unsere Tage. *Hidrológiai Közlöny,* 60. 11. 492—501.
Scheuer Gy.—Schweitzer F. (1981a): A hazai édesvizi mészkőösszletek származása és összehasonlító vizsgálatuk. Origin of the Hungarian freshwater limestone sequences and their comparative study. *Földtani Közlöny,* 111. 1. 67—97.
Scheuer Gy.—Schweitzer F. (1981b): A Gerecse hegység paleokarszthidrogeológiai viszonyainak rekonstrukciója a felsőpannontól napjainkig. Rekonstruktion der paläokarsthydrogeologischen Verhältnisse des Gerecse—Gebirges vom oberen Pannon bis zu unseren Tagen. *Hidrológiai Közlöny,* 61. 8. 333—343.
Schréter Z. (1912a) A budapesti hévforrások földtani fejlődés története (Geological evolution of the Budapest hot springs) — *Magyar Balneológiai Értesítő,* V. 1. 2—4.
Schréter Z. (1912b): Die Spuren der Tätigkeit tertiärer und pleistozener Thermalquellen im Budaer Gebirge. *Mitteilungen aus dem Jahrbuche der kön. ung. Geologischen Reichsanstalt,* XIX. 5. 197—262.
Schréter Z. (1953): A Budai- és Gerecsehegység peremi édesvizi mészkő előfordulásai. Les occurences de calcaire d'eau douce des bords des montagnes de Buda et Gerecse. *A MÁFI Évi Jelentése az 1951. évről,* 111—148.
Szabó J. (1879): Budapest geológiai tekintetben (Budapest from the geologist's angle) — *A magyar orvosok és természetvizsgálók 1879-iki vándorgyűlésének munkálatai, Budapest,* 1—116.
Szentes F. (1943): Aszód távolabbi környékének földtani viszonyai. Die weitere Umgebung von Aszód. Magyar Tájak Földtani Leírása IV. MKFI's publication, *Budapest,* 1—70.
Szentes, F. (1950): Budapest duna bal part távolabbi környékének földtani viszonyai (Geology of the extended neighbourhood of Budapest and the Danube's left riverside). Manuscript, Data Bank MÁFI, T: 124.
Szentes F. (1968): Magyarázó Magyarország 200 000-es földtani térképsorozatához. L—34—I.

Tatabánya (Explanation to the 200 000 geological map series of Hungary. L—34—I. Tatabánya) — Published by MÁFI, *Budapest*, 1—158.

Szentiványi F. (1932): Adatok a Nagy Sváb-hegyen és környékén előforduló levantei mészkő geológiai és paleontológiai viszonyainak ismeretéhez. Beiträge zur Kenntnis der Geologie und Paläontologie des levantinischen Kalksteines vom Nagy Sváb-hegy (Grosser Schwabenberg) und seiner Umgebung. A Ph. D. thesis. *Budapest*, 1—35.

Vendl A. (1934): Reambulation in der Umgebung von Budaörs (Aufnahmsbericht 1919). *Jahresbericht der Königlich Ungarischen Geologischen Anstalt für 1917—1924*, 43—46.

Vendl A (1944): Budapest gyógyforrásai közös védőterületének tervezete (Project of a common conservation area including all medicinal springs of Budapest) — *Hidrológiai Közlöny*, XXIV. 1—41.

Vitális Gy.—Hegyi I. (1982): Adatok a Budapest térségi édesvizi mészkövek genetikájához. Daten zur Genetik der Süsswasserkalksteine im Raume von Budapest. *Hidrológiai Közlöny*, 62. 2. 73—84.

Vitális Gy.—Hegyi-Pakó J. (1973): A hidrotermális hatások és az ércesedés kapcsolata a Dunai andezithegységgel határos karbonátos kőzetekben. Relationship between hydrothermal effects and ore mineralization in the carbonate rocks adjacent to the Danubian andesite mountains. *Bányászati és Kohászati Lapok — Bányászat*, 106. 774—779.

Vitális Gy.—Hegyi-Pakó J. (1974): Hydrothermal and metasomatic phenomena in the Triassic limestone areas bordering on the andesite mountain of the Danube. *Acta Univ. Szegediensis Miner.—Petr.*, XXI. 2. 219—227.

Vitális Gy.—Hegyi-Pakó J. (1976): Hydrothermal alterations of Rocks in the Triassic dolomite areas adjacent to the Danubian andesite mountains. *Acta Univ. Szegediensis, Acta Geographica*, XVI. 1—12. 81—91.

Wein Gy. (1939): Szentendre környékének földtani viszonyai. Über die geologischen Verhältnisse der Umgebung von Szentendre. *Földtani Közlöny*, LXIX. 1—3. 26—52.

Wein Gy. (1977): A Budai-hegység tektonikája (Tectonics of the Buda Hills) — MÁFI Occasional Publications, *Budapest*, 1—76.

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Abbrevations: MKFI = Royal Hungarian Geological Institute;
MÁFI — Hungarian Geological Institute